MODULE 9
UPPER AIR MAPS

OBJECTIVES

At the completion of this module, the student will be able to

1) Identify and contour significant weather features from plotted weather maps
2) Understand the connection of particular features through the depth of the atmosphere
3) Produce a composite chart in order to identify areas favorable for thunderstorm activity

INTRODUCTION

In Module 7, we discussed the basics of map contouring. In Module 8, we learned how to contour and analyze a surface map to identify fronts, pressure centers, moisture fields, and winds. This helped pinpoint areas favorable for thunderstorm development. While this one surface map yields many clues to the thunderstorm forecast picture, forecasters need to see what is occurring throughout the atmosphere. For this we turn to maps which depict the weather conditions at certain levels above the earth's surface.

From previous modules, we know that for thunderstorms we need moisture, lift and instability through multiple layers of the atmosphere. To look for these ingredients, we perform a complete three-dimensional analysis of the atmosphere over a particular area. Easier said than done you say...but really it is easy.

In analyzing the surface map, we found abundant surface moisture from north Texas to eastern Oklahoma. We need to know how substantial this moisture is, how thick or deep it is. We need to know if the winds aloft over the area are strong and if the winds are veering with height. For this we turn to upper air maps.

Upper air charts are constructed for standard pressure levels in the atmosphere: 850 millibars (about 5,000 feet), 700 millibars (about 10,000 feet), 500 millibars (about 18,000 feet), 300 millibars (about 30,000 feet) and 200 millibars (about 39,000 feet). Each map has stations plotted which represent upper air sites across the country. There are approximately 60 stations in the continental United States that produce upper air soundings. This accounts for the limited number of data points as opposed to the data density of the surface map (over 1,000 surface stations nationwide). For instance, Oklahoma has only one upper air site and Texas only seven. Upper air maps are produced twice a day. Upper air balloons are released at 0000 and 1200 UTC in normal weather situations. The costs associated with upper air soundings prohibit them from being taken more often.

THE UPPER AIR PLOTTING MODEL

Figure 9-1 shows the upper air plotting model. You will see many similarities between this plotting model and the surface model we used in Module 8. As in the surface model, the winds are plotted as a series of flags and barbs. Temperature is shown on the upper left. The height of the pressure surface is shown on the upper right, with **dew point depression** on the lower left. The 12-hour height change is plotted on the lower right.

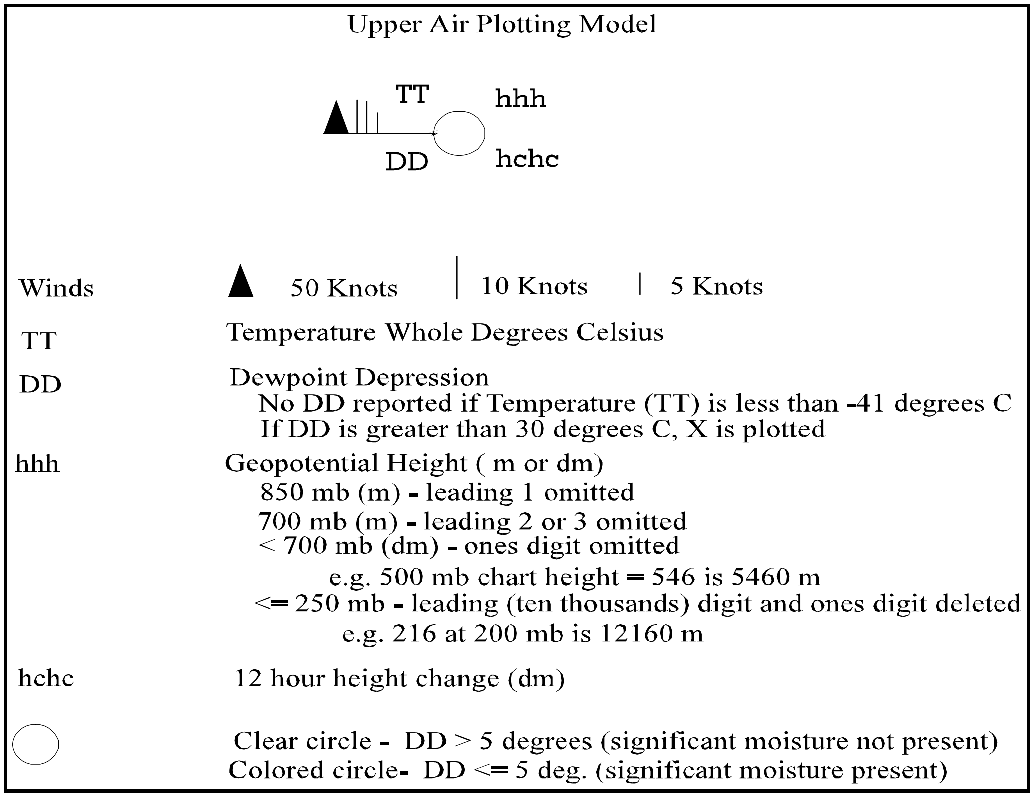


Figure 9-1: Upper air plot model.

There are two tricky things to remember when looking at upper-air maps. First, the height values are similar to (but NOT identical to) the pressure numbers we saw on the surface map. On a surface map, we are evaluating the pressure at a constant height (sea level). On upper air maps, we are evaluating the height of a constant pressure surface. Fortunately, the two quantities are closely related. Low pressure on the surface map can be equated to low heights on the upper air charts, with surface high pressure and upper-level high heights indicating similar conditions.

So why don’t we just use constant height charts throughout the atmosphere? Well, the equation for calculating heights in the atmosphere is related to temperature and pressure. The instrument packages carried by our balloons (see Module 10) can measure temperature and pressure very accurately, while altitude can only be roughly estimated. So, by plugging temperature and pressure into the height equation, we get a more accurate value than we would otherwise (recall some of your Chemistry and Physics lab exercises discussing precision of measurement).

The second tricky aspect of upper air maps is the concept of dew point depression. It is important to remember that this is NOT the actual dew point value. To derive the dew point value, you subtract the dew point depression from the plotted temperature value (TT). For example, if we have a temperature (TT) of 15 degrees and a dew point depression of 7 degrees, then the actual dew point is 8 degrees. If the temperature was -19 degrees and the dew point depression was 12 degrees, then the actual dew point would be -31 degrees.

The rest of this module will look at each of the standard upper air maps, outline the type of information available, and list the critical values every forecaster identifies to pinpoint areas favorable for thunderstorm development. A table of important parameters for each of these upper-air charts is at the end of this chapter.

850 MILLIBAR MAP PLOT

The 850 millibar level is located approximately 5,000 feet (1,500 meters) above sea level. On the 850 mb map facing this page you will see thick solid contour lines which represent the height contours, thin solid lines which represent temperature contours, and thin dash-dot lines which represent dew point contours.

HEIGHT CONTOURS

The numbers which are evaluated for this contour are located on the upper right side of the station circle. On the 850 mb plot, the leading 1 is omitted and the value is in meters. For example, Norman, Oklahoma has 414 plotted on the upper right side. This value indicates that the radiosonde detected a pressure of 850 millibars at 1,414 meters above sea level. On a color plot, height contours are usually drawn in black.

The height fields are critical to identifying areas of high and low pressure. This relationship of heights to pressure can be seen in the eastern half of the country as a ridge of high pressure (higher heights) extends from South Carolina to New York and a trough of low pressure (lower heights) exists from Minnesota to Missouri. A second trough is seen from Oklahoma to southwest Texas. You will also see that the cold front advancing across the country coincides with the axes of these troughs.

Winds in the upper atmosphere flow parallel to the height contours with lower heights to the left of the wind flow. The more closely spaced the contours, the higher the wind speeds. Thus contouring of the height field gives us a clue about wind speed and direction in a certain layer.

DEW POINT CONTOURS

Dew point contours are derived by subtracting the dew point depression in the bottom left corner from the temperature value in the upper left corner. This will give us the dew point value in degrees Celsius (C) for the site. For example, Norman has an 850 mb temperature of 16 degrees C and dew point depression value of 2 degrees C. This would give Norman a dew point value of 14 degrees C. Dew point contours are typically shown in green.

At 850 mb, dew points greater than about 10 degrees C are conducive to severe thunderstorm formation. 850-millibar dew points greater than 15 degrees C suggest severe thunderstorms with heavy rainfall possible. On the map, we see that the area of dew points greater than 10 degrees C covers much of the south-central and southeastern U.S., with the area of dew points 15 degrees C or greater from south Texas to southern Oklahoma.

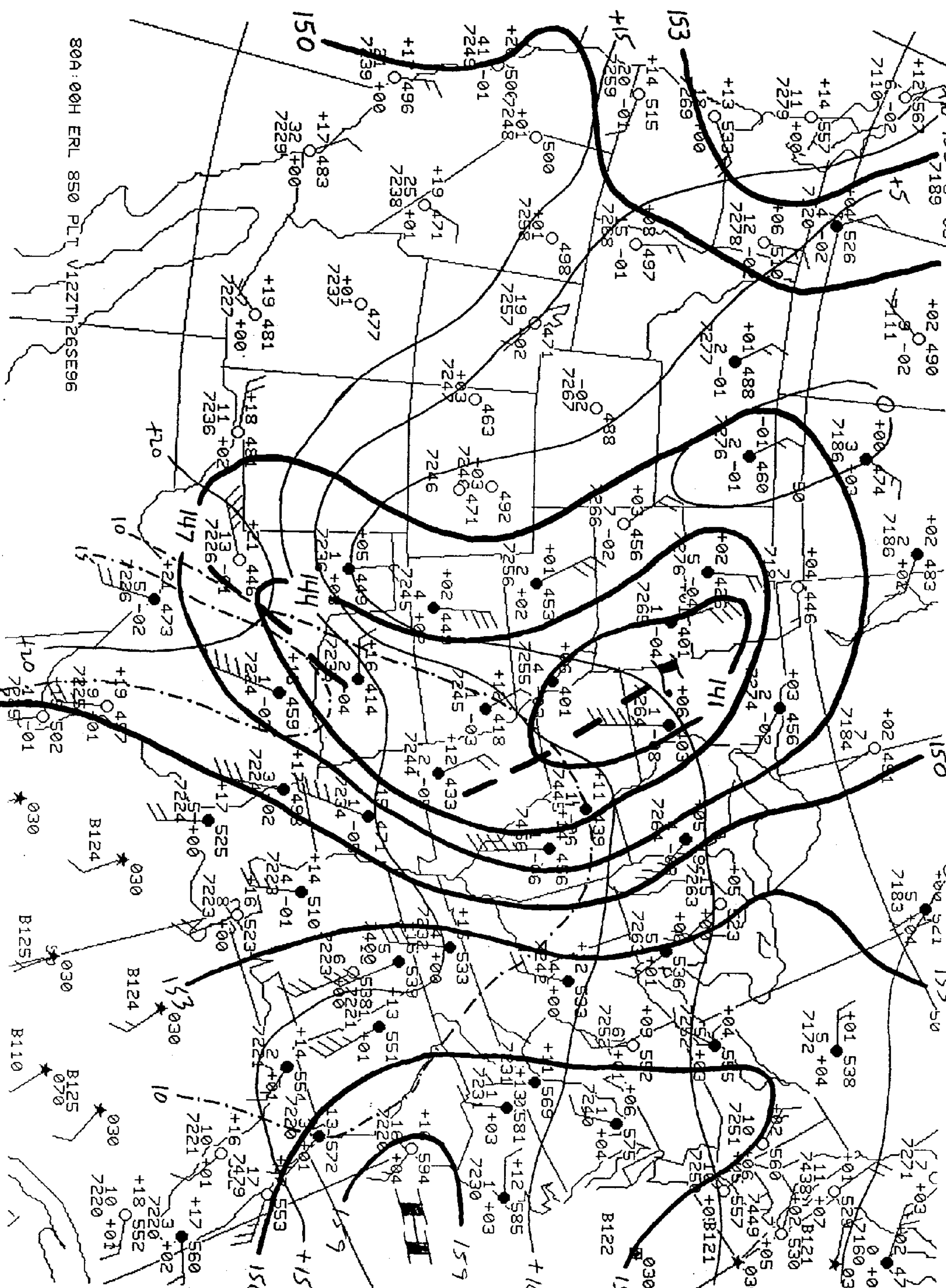
TEMPERATURE CONTOURS

Temperature values are contoured in order to identify areas of dramatic contrast. Contours that are close together or “packed” indicate areas of dramatic temperature change. These temperature changes, in conjunction with the height and wind field, give forecasters the information to identify fronts and other types of boundaries which help to initiate and focus thunderstorm activity. Temperature contours on this map identify a pocket of cold air over the Western Plains, as we have +16 degrees C at Norman, +5 degrees at Amarillo, and +2 degrees at Dodge City, Kansas. Temperature contours are usually drawn in red on color plots.

On this map, we should take notice of the very warm temperatures across southwest Texas. Warm air to the west of the significant moisture is a classic signature for severe weather. The 850 mb winds may move the temperature axis into the moisture area within 12 hours.

HEIGHT CHANGE

The values in the bottom right corner indicate the change in the height of the 850 mb surface over the past 12 hours. Significant changes give us clues to the movement of pressure centers and fronts and also to potential changes in their intensity. For example, an area of height falls means that the 850 mb level has lowered and essentially a valley has formed in the 850 mb surface. Any low pressure centers in the immediate area will likely move toward the height falls much as a ball would roll down an inclined plane. A significant system will have strong height falls ahead of it with strong height rises behind as high pressure filters in. This is illustrated by the area of height rises over the Western Plains with height falls across the Central and Eastern Plains states.


80A:00H ERL 850 PLT V12ZTh26SE96

700 MILLIBAR MAP PLOT

The 700 millibar level is located approximately 10,000 feet (3,000 meters) above sea level. On the 700 mb map facing this page you will see heavy solid contour lines which represent the height contours and light solid lines which represent temperature contours.

HEIGHT CONTOURS

The numbers which are evaluated for this contour are located on the upper right side of the station circle. On the 700 mb plot, the leading 2 or 3 is omitted and the value is in meters. For example, Norman has 047 plotted on the upper right side. This indicates that the radiosonde detected a pressure of 700 millibars at 3,047 meters above sea level. Omaha has 990, indicating a pressure of 700 millibars at 2,990 meters above sea level.

DEW POINT CONTOURS

Dew point values are derived by subtracting the dew point depression in the bottom left corner from the temperature value in the upper left corner. The dew point contours on the 700 mb map are generally few as the required thickness of moisture for thunderstorm development is generally found at heights below this level. Because of this, we have not shown the actual dew point contours on this map. However, you need to pay special attention to large dew point depression values as this indicates a large spread between the temperature and the dew point. This very dry air should be contoured in brown. Very dry air in the mid levels of the atmosphere will help destabilize a column of air, making it favorable for severe thunderstorm development. On this map, the air at 700 mb is fairly moist over the Southern Plains states. This would suggest more of a heavy rainfall/flood potential than a severe weather threat.

TEMPERATURE CONTOURS

Temperature values are contoured in order to identify areas of dramatic contrast. Contours which are close together or “packed” indicate an area of dramatic temperature change. However, these changes usually aren’t as pronounced as on surface maps. Temperature changes, in conjunction with the height and wind field, give forecasters the information to identify fronts and other types of boundaries which help to initiate and focus thunderstorm activity. On the 700 mb chart, very warm temperatures will hinder thunderstorm activity. This is the “cap” or “lid” discussed in Module 2. You will often hear the words “ We have to overcome this cap” or “ I think the upper system will help to erode the cap”. Each of these statements indicate that some process must occur to overcome the negative impact of these warm 700 mb temperatures. On this map, we see warm 700 mb temperatures (greater than 10 degrees C) over south Texas and southern California.

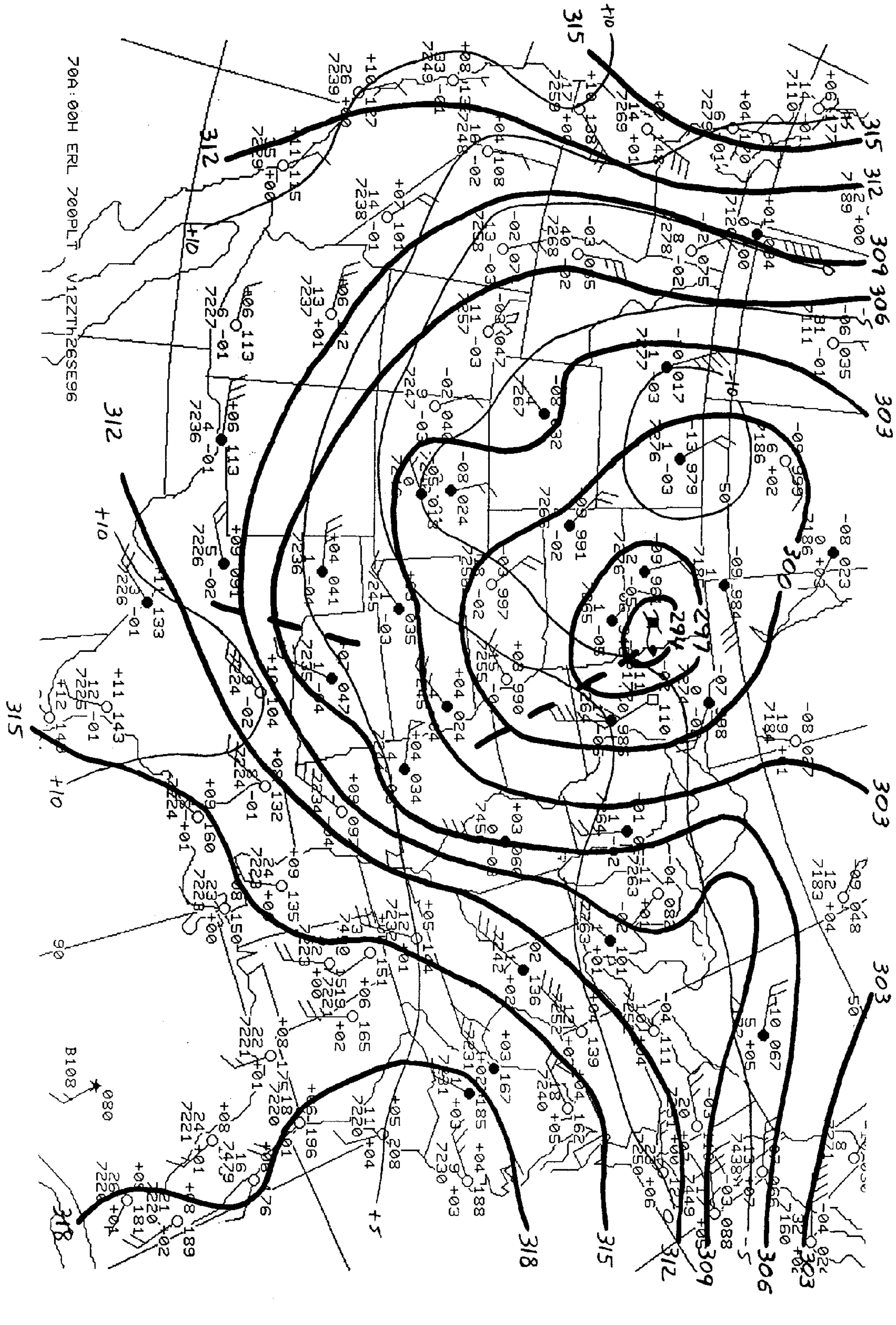
HEIGHT CHANGE

The values in the bottom right corner indicate the change in the height of the 700 mb surface over the past 12 hours. Contouring of these areas can pinpoint “couplets.” Couplets are areas where large height falls exist next to large height rises. A rise-fall couplet indicates an upper level trough. These areas are the location of tremendous energy exchanges which can dramatically affect the atmosphere and thus a storm’s environment upon passage.

WINDS

On the 700 mb plot, forecasters examine the wind field to see if drier air, as described in the dew point contour discussion, will be brought into an area. This frequently happens in the springtime as southwest winds bring warm, desert air off the Mexican Plateau into Texas and Oklahoma. It is important to consider changes in the contoured fields that may take place over a given location within the next 12 hours as the wind advects higher or lower values downstream. On this map, drier air over Arizona and southern California will brought eastward toward Texas and Oklahoma by the prevailing winds.

The 700 mb winds can also give us a clue regarding the speed and direction thunderstorms will move if and when they develop. Thunderstorms typically move along with (or slightly to the right of) the mean wind from the surface through 20,000 feet. The 700 mb wind is often a good first guess at this mean wind. Knowledge of the storm motion is critical to determining the wind shear patterns which help storms become severe or tornadic.


70A:00H ERL 700PLT V12ZTh26SE96

500 MILLIBAR MAP PLOT

The 500 millibar level is located approximately 18,000 feet (5,600 meters) above sea level. On the 500 mb map facing this page you will see heavy solid lines which represent the height contours and thin solid lines which represent temperature contours.

HEIGHT CONTOURS

The numbers which are evaluated for this contour are located on the upper left side of the station circle. On the 500 mb plot, the ones digit is omitted with the value in tens of meters. For example, Norman has 574 plotted on the upper left side. This indicates that the radiosonde detected a pressure of 500 millibars at 5,740 meters above sea level. It is the 500 mb map height contours which will indicate upper level thunderstorm support in the form of upper level highs and lows.

Another element we look for in the contoured height field is diffluence. Diffluence is a pattern in which the height contours spread out, much like a fan. We see some weak diffluence across Oklahoma and north Texas, and another area from Illinois to Tennessee. Areas of diffluence often indicate areas of enhanced upward motion, which in turn make the atmosphere more conducive to severe storm development.

TEMPERATURE CONTOURS

Forecasters analyze 500 mb temperatures to help identify troughs. They are also very interested in temperatures which are markedly cooler than other surrounding sites as this indicates a “cold pool.” All forecasters are aware of the fact that to destabilize a column of air you must “warm the bottom and cool the top.” We look for warm air moving into an area at the 850 mb level and cold air moving into the same area in the upper levels. On the 500 mb plot you will see -10 to -14 degree C air from Arizona and New Mexico moving into -8 to -9 degree C air over Oklahoma and Texas.

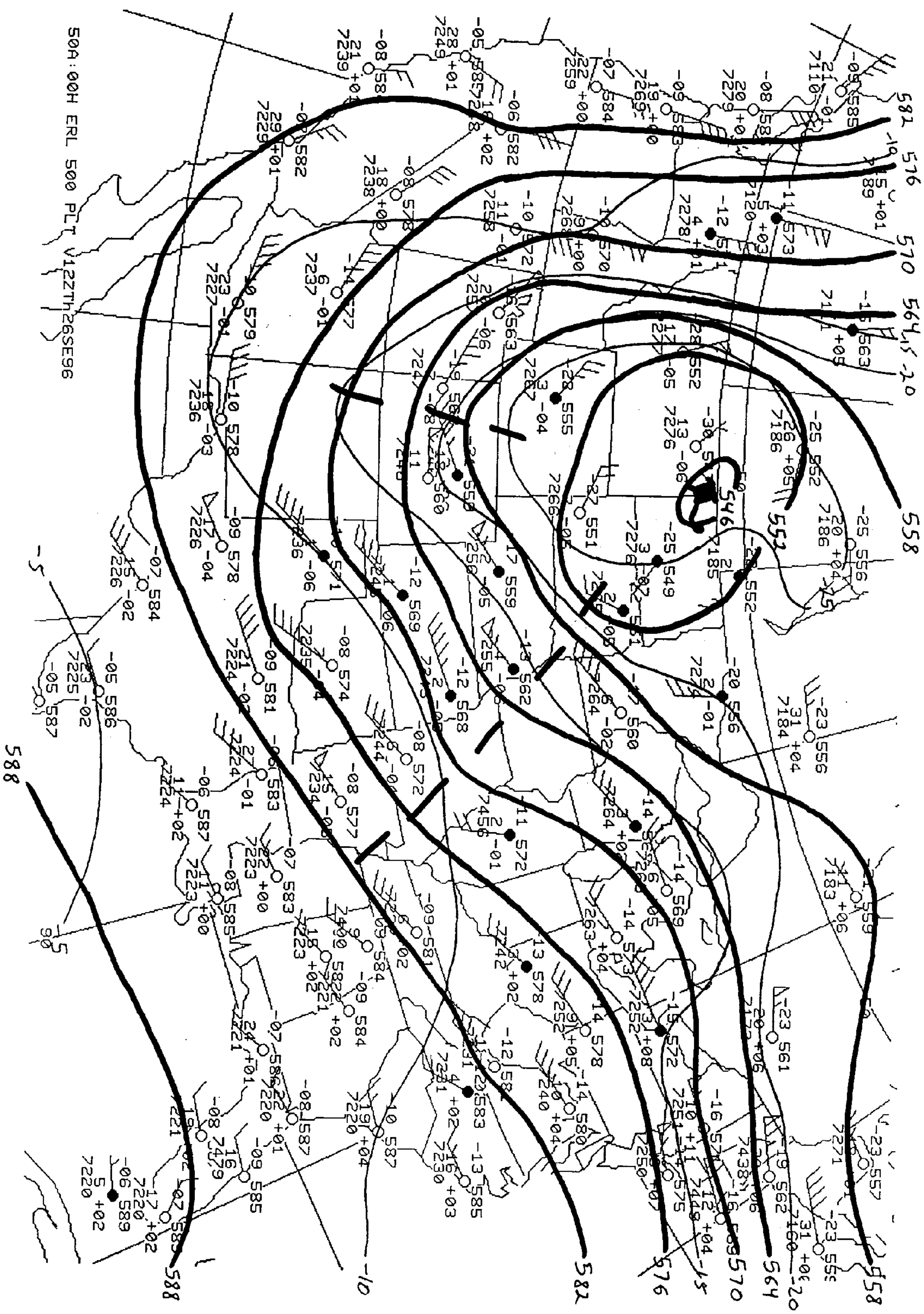
Forecasters are also interested in temperature lapse rates. Lapse rates tell forecasters how quickly the temperature cools between layers and gives us an idea of how explosive the storm environment is. We can derive a 700-500 mb lapse rate by taking the 700 mb temperature at Fort Worth and subtracting Fort Worth’s 500 mb temperature. This yields a value of 19 degrees (-9 subtracted from +10), a fairly substantial temperature change. These lapse rates are also key ingredients for various storm indices which attempt to pinpoint the type of thunderstorm and associated severe weather which might occur if thunderstorms develop.

HEIGHT CHANGE

The values in the bottom right corner indicate the change in the height of the 500 mb surface over the past 12 hours. Contouring of these areas can pinpoint “couplets.” Couplets are areas where large height falls are next to large height rises. A rise-fall couplet indicates an upper level trough or impulse. These areas are the location of tremendous energy exchanges which can dramatically affect the atmosphere and thus a storm’s environment upon passage.

WINDS

Winds at the 500 mb level are analyzed for speed and direction. High wind speeds may indicate the presence of a jet stream (large wind core) or jet streak (small wind core). Researchers have shown that jet streaks are divided into quarters, with the left front and right rear quadrants being favorable areas for uplift and therefore thunderstorm support. These strong winds also provide the ventilation needed to move the tops of thunderstorms downstream allowing the updrafts to grow unhindered. On color analyses, wind speed contours are usually drawn in purple. On the accompanying map, a jet stream of moderate intensity (40-50 knots) extends from Arizona east-northeastward to the central plains. A stronger jet streak of 50-75 knots is evident to the west of the upper low over the northern Rocky Mountain states.



200 MILLIBAR MAP PLOT

The 200 mb surface is located about 39,000 feet (12,000 meters) above sea level. This map is examined for strong winds (jet streams or jet streaks) which may be present.

HEIGHT CONTOURS

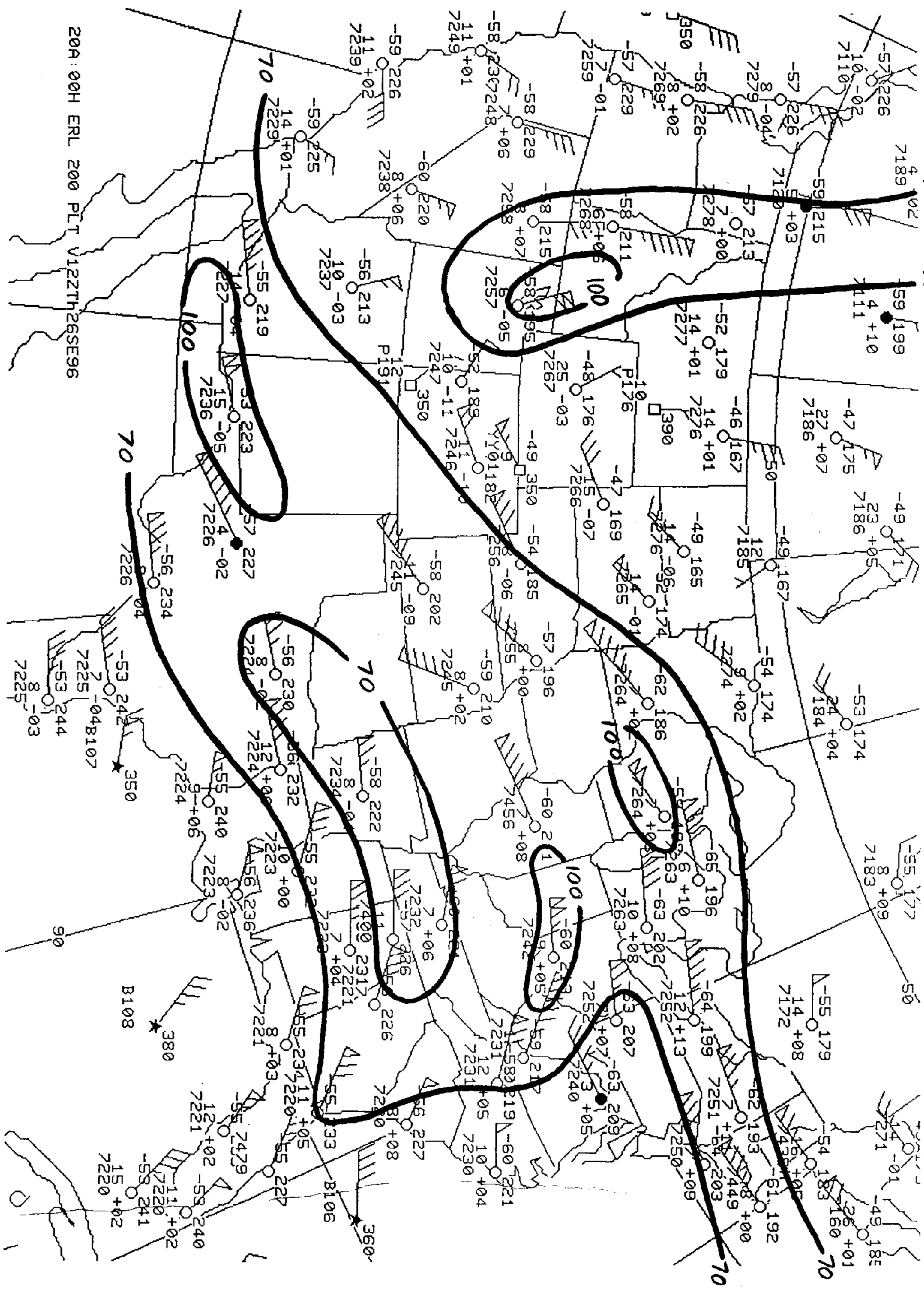
The numbers which are evaluated for this contour are located on the upper left side of the station circle. On the 200 mb plot, the leading ten thousands digit and the trailing ones digit are omitted with the value in tens of meters. For example, on the accompanying map, Fort Worth has a value of 230 plotted. This means that the radiosonde detected a pressure of 200 millibars at 12,300 meters above sea level. Because of the extreme altitude of this pressure level, height contour analyses are of lesser value than those found lower in the atmosphere.

WINDS

On the 200 millibar plot, wind speeds may be contoured just like temperature and height fields. If a jet stream is present you will see a core of very strong winds surrounded by lighter speeds. From the accompanying map, notice that the wind speed contours are elongated along the direction of the flow. This will allow the jet to be quartered to identify the left front and the right rear quadrants. Contours are usually drawn for wind speeds around 60-70 knots and around 100-120 knots.

On this map, we see two jet streams across the country. The first, larger jet, extends from southwest to northeast across much of the country. This jet stream has several jet streaks embedded in it. Two streaks are evident over the upper Midwest, while a third appears over southern New Mexico. These jet streaks, especially the left-front and right-rear quadrants, mark areas of enhanced upward vertical motion. Note that the contoured area from north Texas to Tennessee is an area of relatively weak wind speeds (less than 70 knots).

The second jet stream is smaller in size and extends from western Canada southward to Utah. This jet stream appears to have one jet streak embedded in it. The jet streak is moving over relatively cold lower-level air (refer back to the 700 mb map and look at the temperatures in this area). This system may be associated with significant snowfall over the mountainous regions.


20A:00H ERL 200 PLT V12ZTH26SE96

COMPOSITE CHART

As you see there is a lot of information to be gleaned from these maps. The first order of business for most forecasters when they arrive at the forecast desk is to analyze the surface map and the upper air charts. This gives the forecaster a snapshot of what is going on and how well the models appear to be performing. But how do forecasters arrive at this snapshot?

The answer is a composite chart. This chart enables forecasters to extract the elements critical for a particular weather event from each upper air chart and place them on a single map. For this exercise we will focus on those ingredients which are important for severe thunderstorm development.

The ingredients important for severe weather development are listed in the critical value table on page 9-14. We will review each of these ingredients here. It might help if you actually colored your diagram as we go along. Note that the graphic does not have geographical boundaries as it is a just an illustration of the concept.

On the surface chart, we analyzed a surface low in central Oklahoma with a warm front extending to the east and a cold front trailing southwestward from the low. On the composite chart, you would color the warm front red with red half-circles and the cold front blue with blue triangles.

On the 850 mb chart, high dew points and the wind field that transports the moisture are important. On our 850 mb chart, we saw an area of moisture over the south-central and southeastern United States. Represent this area on the composite chart with scalloped edges and shaded green. The low level jet (a core of strong winds associated with the area of higher moisture) is evident from south-central Texas to central Arkansas to central Illinois. On the composite chart mark the low-level jet with a thin black arrow in the direction of the wind flow.

The temperature contours also come into play on the 850 mb chart. We noticed the warm temperatures across southwest Texas. This represents a temperature ridge. On the composite chart, show this as a dashed red line and shade the enclosed area red.

Moving to the 700 mb map, we identify pockets of drier air. On our map, this drier air was located in southern California, Arizona, and New Mexico, with the winds blowing toward the Southern Plains. On the composite chart, this area is bounded by a hatched line and shaded brown.

On the 500 mb map, our attention shifts to cold pools and the presence of jet streams. In the western United States we identified an area of cooler 500 mb temperatures. We also noted that the wind field had several small areas of diffluence. These two observations allow forecasters to place the jet streams. It is likely that both of the jet streams we observed are segments of the "polar jet stream". The subtropical jet is probably south of our analysis area.

The placement of the jets also becomes more apparent with the 200 mb analysis. We analyzed the strongest winds over the southern and eastern half of the country, and over the northern and central Rocky Mountains. This verifies our theory of a polar jet stream with two primary segments. Mark these upper level jet streams with broad black arrows.

As you can see, the composite chart has given us a quick picture of where these thunderstorm ingredients come together. We can now narrow our focus by examining upper air soundings, analyzing additional surface charts, and exploring the various forecast model runs.

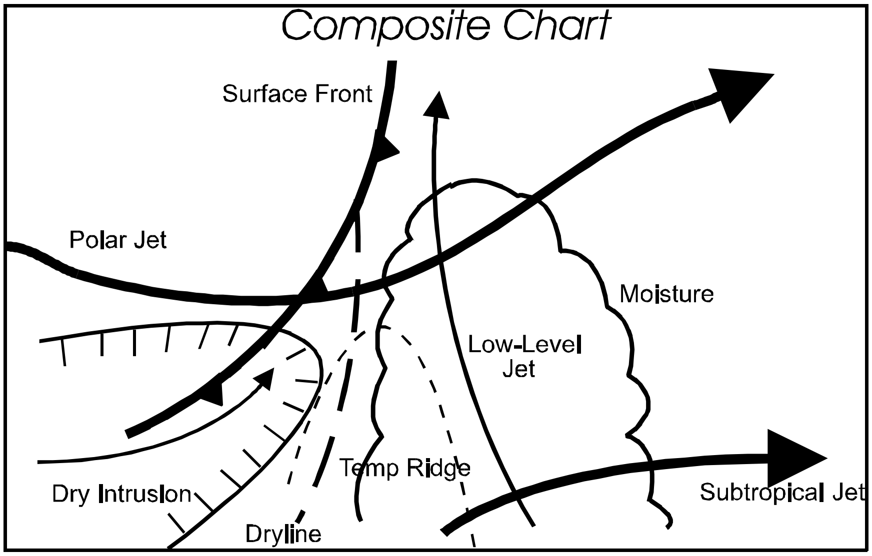


Figure 8-2: Composite analysis technique.

CONTOUR INTERVALS AND CRITICAL VALUES

It is very important to understand that the contour values which are listed here are not concrete. They are flexible from one event to another. Forecasters will often pick different beginning contour values to highlight parameters which they believe are critical although the contour intervals often stay the same.

<u>850 MILLIBAR MAP PLOT</u>

Height -	Begin with 156 with intervals of 30 meters, i.e. 153, 150, 147, 144...
Dew Point -	Begin with the highest dew point with intervals of 2 degrees, i.e. 10, 8, 6...
Temperature-	Begin with 25 and contour for every 5 degrees, i.e. 10, 15, 20, 25...
Height Change -	Begin with + or - 6 with intervals of 2. Don't contour values < +/-2

CRITICAL VALUES

Height -	Closed pressure centers ; frontal boundaries
Dew Point-	Values in excess of +10
Wind -	Low level jet, 30 knots or greater
Temperature-	Large contrasts identifying frontal boundaries; narrow corridor of warm temperatures (+ 16 or greater) near high dew point values
Height Change-	Values in excess of + or - 4

<u>700 MILLIBAR MAP PLOT</u>

Height -	Begin with 312 with intervals of 30 meters, i.e. 309, 306, 303, 300, 297...
Dew Point-	Begin with highest dew point with intervals of 2 degrees Begin with dew point depression of 10 degrees with intervals of 5
Temperature-	Begin with + 20 and contour for every 5 degrees, i.e., 15, 10, 5, 0, -5...
Height Change-	Begin with + or - 6 with intervals of 2. Don't contour values < +/-2

CRITICAL VALUES

Height-	Closed pressure centers; ridge axis and trough axis
Dew Point-	Values in excess of +4; dew point depression values greater than 20
Temperature -	Large contrasts to place fronts; temperatures of +10 or greater. Important: temperatures required to "cap" the atmosphere will vary according to season. Check the sounding to be sure you have a true "cap"
Wind -	Wind speeds at least 25 knots
Height Change-	Values in excess of +/- 4; Look for rise/fall couplets

<u>500 MILLIBAR MAP PLOT</u>

Height-	Begin with 576 with intervals of 60 meters, i.e. 570, 564, 558, 552...
Temperature-	Begin with -5 with intervals of 5 degrees, i.e. -10, -15, -20, -25...
Height Change-	Begin with +/- 6 with intervals of 2. Don't contour values < +/- 2.

CRITICAL VALUES

Height-	Closed pressure centers; ridge axes and trough axes
Temperature-	Values of -15 or colder moving into an area of warmer air; 700 to 500 mb temperature changes in excess of 20 degrees; 850 to 500 mb changes in excess of 30 degrees
Height Change-	Values in excess of +/-4; Look for areas where height rises border height falls to identify impulses and couplets
Winds-	Winds 50 knots or greater; jet streams/jet streaks; diffluent flow areas

<u>200 MILLIBAR MAP PLOT</u>

Winds-	Begin with the highest wind speed with intervals of 20 knots

CRITICAL VALUES

Winds-	Speeds in excess of 60 knots and in excess of 100 knots; Identify left front and right rear quadrants of jet streaks